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THE MULTI-CENTER TMA SYSTEM ARCHITECTURE AND ITS IMPACT ON INTER-FACILITY COLLABORATION

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Abstract

The success of the Traffic Management Advisor (TMA) system at Fort Worth Air Route Traffic Control Center (ARTCC) and other ARTCCs has prompted the further development of TMA to address problems in the congested environment of the Northeast corridor of the US National Airspace System (NAS). This region is characterized by terminal areas whose arrivals approach from more than one ARTCC thereby requiring greater coordination in arrival traffic planning. NASA and the FAA are developing a Multi-Center Traffic Management Advisor (McTMA) tool that introduces a new infrastructure to allow individual TMA systems to communicate with each other, thereby forming a McTMA network. The prototype system allows the four ARTCCs of the northeast (New York, Washington, Boston and Cleveland) and the Philadelphia (PHL) Terminal Radar Approach Control Facility (TRACON) to share a regional view of the arrival demand at the PHL airport. This shared view will enable these facilities to proactively address PHL congestion issues through better coordination and management of traffic into an adjacent air traffic control unit, be it a sector or a facility. This paper presents a high-level description of the McTMA architecture and potential collaboration possibilities that may arise from using the system.

Introduction and Background

TMA and McTMA Sites

As part of its Free Flight Phase 1 Program, the Federal Aviation Administration (FAA) has completed the deployment of the Traffic Management Advisor (TMA) tool at six sites, following the successful field test of the prototype software at the Fort Worth (ZFW) Air Route Traffic Control Center (ARTCC). The six ARTCCs or Centers are Oakland (ZOA), Los Angeles (ZLA), Denver (ZDV), Minneapolis (ZMP), Atlanta (ZTL), and Miami (ZMA). The Multi-Center TMA (McTMA) project exposes four new Centers to the demand prediction and scheduling capability that is similar to what TMA offers. The Cleveland (ZOB), New York (ZNY), Washington (ZDC) and Boston (ZBW) Centers join the Philadelphia (PHL) Terminal Radar Approach Control Facility (TRACON) in the McTMA project. The Northeast sites were chosen because of their unique challenges.[1] Figure 1 shows the coverage of the TMA and McTMA systems over the National Airspace System (NAS).

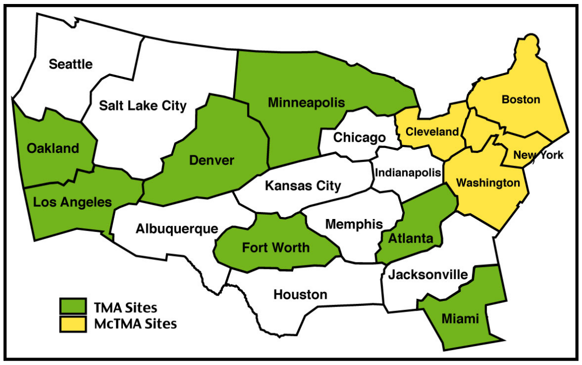

Figure 1: TMA and McTMA Centers

Operations in PHL and Vicinity: Unique Challenges

When compared to ZFW, the Northeast presents new airspace challenges that need addressing by the McTMA system. This section presents three topics that impact the design of the McTMA system.

Sector Airspace Layout

The Northeast geographic layout and airspace description present a dramatically different view of traffic from that of the Fort Worth Center. Overall, sizes of flow management sectors are smaller. The controllable times are shorter. There are more closely-spaced airports with greater congestion both on the ground and along the arrival routes. The Northeast sectors handle more crossing traffic, and more aircraft are climbing or descending through the transition flight regime.

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Not only are the sector airspaces smaller in the northeast, they are, in general, oblong in shape. This shape may help or hinder the controllability of the traffic. For example, Sectors 26 and 27 in New York and Sectors 61 and 62 in Cleveland Center (Figure 2) run lengthwise in the west-east direction, which is the direction of flow that feeds the Bunts corner post of the PHL TRACON. The size and geometry of the sectors are sufficient to provide some amount of controllability by vectoring aircraft to the north or to the south. In Washington Center, the sectors that feed the Terri (southwest) corner post (Sectors 10, 12, and 32) are shaped lengthwise from the northeast to the southwest. The geometry is in accordance with the arrival routes, but the traffic is usually delivered from the west-east direction. Hence, the traffic is entering the sector via the short side, thereby limiting the controller's ability to vector the aircraft. Figure 2 illustrates the Center boundaries (thick solid lines), sector boundaries (dashed lines) and the PHL arrival routes (thin solid lines). Please note that the corner post descriptions are defined in Figure 4.

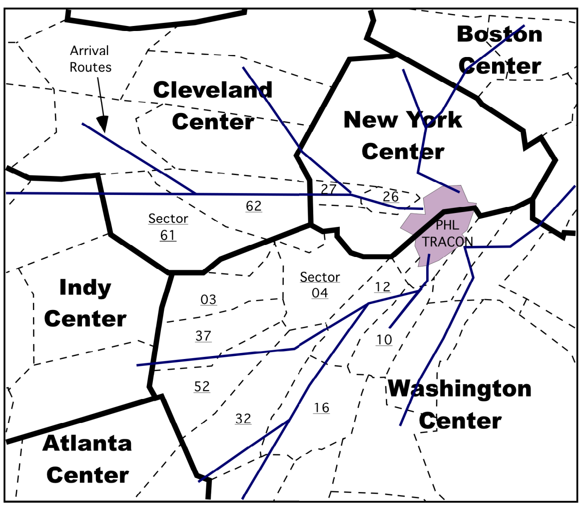

Figure 2: Sector Layouts in the Northeast

The size of the sector also dictates the amount of delay that a sector can absorb. It may be such that the delay absorption profile between adjacent sectors may not be linear. As an example, one sector may be able to absorb four minutes, the next sector can absorb zero minutes, and then the following sector has to absorb a higher amount to compensate. From simulations conducted at NASA Ames, it was discovered that New York Sectors 26 and 27 might not be able to absorb any amount of delay. So it is up to Sectors 61 and 62 of Cleveland to absorb all or most of the delay. Excess delay in these sectors must be passed further upstream into Indianapolis Center (Figure 2).

The Philadelphia TRACON Airspace

The PHL TRACON straddles two Center boundaries, ZNY and ZDC. Each of these Centers controls its own flow into PHL TRACON. In contrast, the Dallas-Fort Worth (DFW) TRACON is located in the middle of ZFW airspace with ZFW controlling all flow into DFW. Figure 3 shows an overlay (dashed line) of the ZFW airspace onto the Northeast Centers. The dimensions of ZFW are about 650 nautical miles in the West-East direction and 325 nautical miles in the North-South direction. The PHL TRACON is located in the center of the picture.

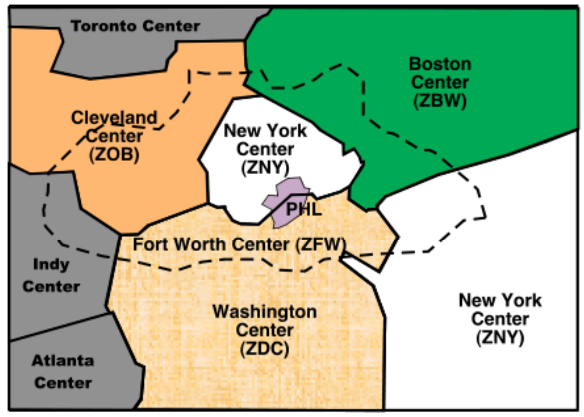

Figure 3: Northeast Centers with ZFW Overlay

This uncommon arrangement of airspace adds complexity to the planning process. Aircraft that leave ZBW airspace with a PHL destination are typically routed over the VCN or southeast corner post. However, the flight plans are routed in a circuitous manner from ZBW (high altitude sector) to ZNY (high sector), to ZDC (low), and then back to ZNY (low), because ZNY "owns" the TRACON.

As an additional constraint, the TRACON communicates directly with only one Host Computer System (HCS or Host). In this example, ZNY communicates and coordinates directly with PHL TRACON. When the TRACON changes the airport acceptance rate (AAR), it relays that information to ZNY, who in turn puts restrictions onto the PHL arrival streams from the adjacent Centers. The PHL example highlights a requirement for an architecture that can share data between multiple systems to build appropriate aircraft trajectories, mirroring the communication flow of the Hosts.

Tower-Enroute Control (TEC) Traffic

Another distinction between these airspaces involves the handling of Tower-Enroute Control (TEC) traffic. TEC aircraft are flights that enter the TRACON via an abutting TRACON and not from an ARTCC. As such, they are not acknowledged by the Host system. This traffic can comprise up to 40% of the traffic into PHL.[1] Figure 4 shows the six abutting TRACONs that deliver TEC flights into Philadelphia: Allentown, New York, Atlantic City, Dover, Baltimore, and Reading. Also presented in Figure 4 are the five corner posts that feed the PHL TRACON: Bunts, PTW (Pottstown), Mazie, VCN (Cedar Lake), and Terri.

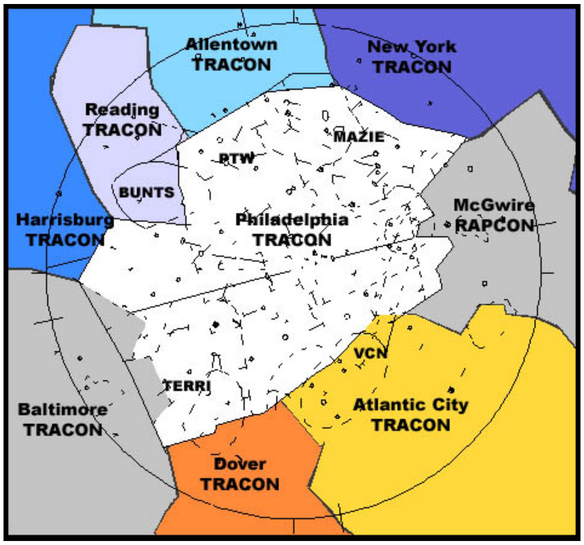

Figure 4: Abutting TRACONs to Philadelphia.

The absence of the TEC flights from the Host distorts the AAR (capacity) and capability of the TRACON. The Host receives flight plans for the TEC aircraft but because they are outside the Center's airspace (lower in altitude) the Host filters and removes them from further flight plan processing.

ZFW considers TEC flights a non-issue due to their limited impact on the facility. It was therefore not a design requirement for the TMA system. While immaterial at ZFW, the Northeast traffic necessitates the inclusion of the TEC flights into the design of the McTMA architecture to effectively capture the true nature of the demand picture at the TRACON.

The McTMA Model

An examination of the PHL traffic showed that although the Centers have reputable traffic flow management (TFM) plans; they lacked an up-to-date regional game plan. The Traffic Management Unit (TMU) and Traffic Management Coordinator (TMC) at each Center did not have a unifying big picture of the traffic demand. As the name suggest, a game plan is a TFM guide and a set of agreements developed by the Centers to coordinate inter-facility flows. Using such data as atmospheric readings and seasonal traffic patterns, a new game plan is selected each morning that sets the tone for the control of nominal traffic throughout the day. The McTMA system architecture was therefore defined to include features that provide current information to the TMUs so they can effectively implement flow management techniques that allow each Center ample time to execute a coordinated plan.

McTMA Objective

The objective of the McTMA project is to alleviate arrival congestion through adjacent air traffic control facilities by redistributing the delays and workloads further upstream. Each participating Center will partake in the overall scheme to siphon a portion of the delay and workload before handing-off the aircraft to an adjacent facility. Upstream facilities can absorb a higher percentage of overall delays and can apply delaying techniques earlier, thereby preventing a last-minute reaction type of behavior near the TRACON. This technique uses a scheduling algorithm that generates time and delay values as a way to meter or control aircraft across the airspace. McTMA applies the same time-based metering paradigm as TMA but on a larger, distributed scale.[2]

The Design of the McTMA Architecture

The functionality of the McTMA system mirrors that of the single-Center TMA system. Both systems predict arrival demand, generate arrival sequences and schedules, and calculate aircraft delay absorption values. Controllers then impose delay mechanisms upon the aircraft so airport capacity is not exceeded. Like the TMA model, the McTMA model requires the installation of the software at each ARTCC facility.

Whereas TMA was designed to be a self-sufficient independent system, the advantages of the McTMA system become apparent when it is connected into a network. The McTMA system extends the aircraft prediction and controllability horizon into upstream air traffic control facilities. Cooperation and data sharing are key components of the McTMA architecture. A network of McTMA systems can be used to share data and aid inter-facility collaboration. In addition, the McTMA system at a particular ARTCC behaves and functions just like a TMA system when it is installed as a "stand-alone" system. McTMA will either be installed as a new system or it will replace an existing TMA system at an ARTCC.

Following are two figures that illustrate the architecture of the McTMA system. Figure 5 shows the data sharing architecture among the McTMA systems and their respective Hosts to capture and provide a regional view of the traffic. Figure 6 shows the software modules that make up the McTMA system. Subsequent sections provide details of the elements depicted in the figures.

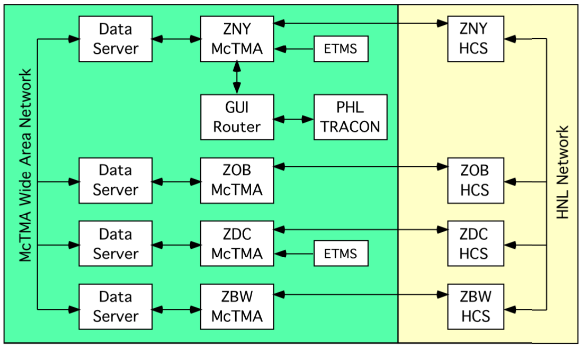

Figure 5: McTMA Wide-Area-Network Topography

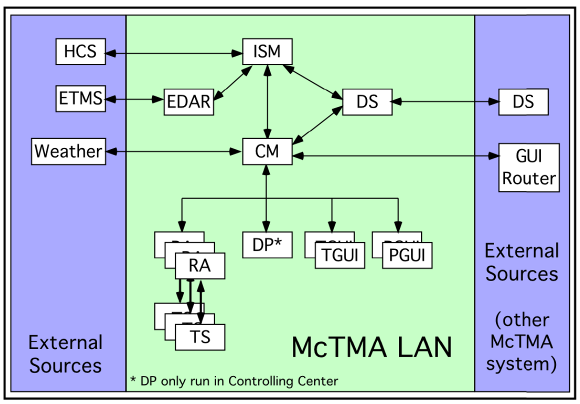

Figure 6: McTMA Software Modules.

McTMA Network

The McTMA network is a homogenous network; mixing TMA and McTMA systems on the WAN is not possible. The network requires all participating Centers to have a McTMA system installed. Sites running TMA would have to upgrade their software to McTMA before connecting to the McTMA network. Further, the infrastructure of the stand-alone TMA system is not designed to communicate with other TMA systems. The fundamental infrastructure differences between the two systems are described in the McTMA Software Modules section.

The nomenclature describing the functionality of each McTMA system and how it contributes to network data sharing is described below. A Center can be defined as a controlling, an arrival, or an adjacent facility, or any combination thereof. Because there is one McTMA system per Center, a controlling Center owns the controlling system.

The controlling Center controls the Dynamic Planner (DP) scheduler generating all Scheduled Times of Arrival (STAs) to the arrival airport. The schedules generated by the controlling Center are made available to the arrival and adjacent systems. The situation is unique for the PHL airport because two Centers each own a portion of the arrival gates to the PHL TRACON. ZNY has ownership of the PHL TRACON and all flight-plan processing eventually gets routed to the ZNY Host. For the rest of this paper, ZNY is the controlling Center. (Please note that the meter fix is sometimes referred to as an arrival gate or a corner post because the arrival streams are funneled and routed through these posts.)

The arrival Center controls the meter fix that feeds aircraft into the TRACON and contains the destination airport within its borders. The arrival Centers are New York controlling the Bunts, PTW, and Mazie meter fixes, and Washington controlling the Terri and Cedar Lake (VCN) meter fixes. These facilities provide the controlling Center with interim demand forecast using data collected from their local Host computer.

An adjacent Center feeds aircraft into the arrival and controlling Center. It provides the arrival Center with an extended forecast of the traffic demand. Because it does not own an arrival gate, the adjacent facility generates partial-trajectory Estimated Times of Arrival (ETAs) and forwards the data to the controlling Center, which returns STAs. In this scenario, Cleveland and Boston are adjacent Centers to New York.

Figure 5 shows the four McTMA Centers, ZNY, ZOB, ZDC, and ZBW on the Wide Area Network (WAN). The PHL TRACON uses the GUI router to extract display information that it needs. The requests are routed through to the Communication Manager (CM) and data server (DS) processes at ZNY (Figure 6). These processes are described more fully below. The data servers from other sites then supply the ZNY data server with the information that it requested. On the Host Computer System (HCS) side, each Host shares data over the HID/NAS LAN (HNL) network.[9]

The architecture of the McTMA network is straightforward and builds upon the TMA setup. Each McTMA system communicates with the local Host computer and shares that data with other McTMA systems within an architecture that parallels that of the Host's network. The two-way data communication connection between the McTMA system and its local Host provides a direct link between the two networks. The two-way communication allows McTMA to receive data such as flight plans, tracks, and other messaging data from the Host. It also allows the Host to receive scheduling, sequence, and delay data from McTMA. The PHL-TRACON is also shown as being a part of the McTMA network although there is no corresponding Host connection. This illustrates the system's capability to distribute shared data to other facilities enabling traffic flow decisions to be made with information not normally available. Each McTMA system can receive data from other sources besides the Host, including weather data and ETMS data. In addition, the controlling Center, New York, can indirectly collect data from the TRACON computer (Automated Radar Terminal System - ARTS) via the ETMS interface.

McTMA Software Modules

The McTMA architecture employs a Local Area Network (LAN) for inter-process communication and a Wide Area Network (WAN) for inter-McTMA data sharing. The LAN topography for McTMA is very similar to TMA with the exception of three new software modules: the Data Server (DS), the GUI router, and the ETMS Data Archive Router (EDAR).[2, 5] Through EDAR, McTMA can connect to an additional data source, the Enhanced Traffic Management System (ETMS). Figure 6 illustrates the software modules that make up the McTMA system. Interactions with external sources and systems are also presented.

Core Modules

The Input Source Manager (ISM), Communication Manager (CM), Route Analyzer (RA), Trajectory Synthesizer (TS), Dynamic Planner (DP), Timeline Graphical User Interface (TGUI), and Planview GUI (PGUI), provide the same core services as they currently do in the TMA system.[2, 5] Not discussed in this paper is the Monitor and Control (M&C) module. The M&C module checks the health of the system and alerts the user of downed processes via a GUI interface. The module is implemented in both the TMA and McTMA systems.[8]

The ISM manages and correlates aircraft data from external data sources such as the Host and ETMS. The CM is the central process that routes internal messages and data, and communicates with all other TMA processes. CM also process weather data and disseminates it to the other modules. The RA and TS work hand-in-hand to generate the four-dimensional trajectory calculations that produce accurate ETAs. The ETA represents the earliest time the aircraft can arrive at the reference point if it were the only aircraft in the system. The DP takes the aircraft's ETA and applies to it various systems constraints, such as the airport acceptance rate, in-trail separation between aircraft types, runway wake vortex, etc., to generate the system's preferred arrival time or STA. The delay absorption value for the aircraft is the difference between the ETA and STA. Air traffic controllers delay aircraft by changing heading, speed, altitude, or some combination thereof to meet the STAs at a predefined location. These locations can be an outer-arc or a meter fix. Two GUI processes provide visual displays for users to monitor and manipulate traffic management functions. Both GUIs can display all arrival aircraft within the system. The TGUI provides these data in a temporal format and the PGUI displays them in a spatial format.[2]

Data Server Module

A new key module that defines McTMA is the Data Server (DS). The DS functions as a repository for both incoming and outgoing McTMA-calculated data and raw flight data. The data can be processed locally or externally and then shared with other systems.[8] Figure 5 shows that the Data Server provides a direct and single point of linkage between the McTMA systems. The DS uses a publish-and-subscribe communication model to exchange data. The current model has the publisher broadcast data to all subscribing agents. It will be up to the subscriber to discard data that it does not need. The DS uses the TCP/IP library when communicating with the ISM and CM, for backward compatibility. Each Center controls the data it publishes and sets subscription parameters through adaptation files.

Figure 7 shows a simplified model of the interactions between the Data Servers and the flow of data between them. This illustration describes two adjacent Centers and one controlling Center. The data flow becomes increasingly more complex if the two adjacent Centers are also communicating with each other. The end state is reached when a controlling Center takes on the additional role of an adjacent Center, feeding enroute data to neighboring controlling Centers.

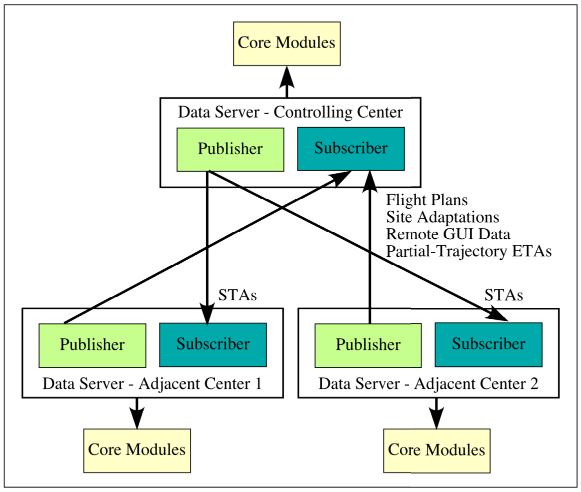

Figure 7: Information Flow Between Data Servers

The adjacent Centers calculate partial-trajectory ETAs for aircraft that over-fly their airspace and publish that data to the subscribing agent in the controlling Center. The DP in the controlling Center calculates STAs for each of those aircraft it receives from the adjacent Centers and then publishes the data to Centers subscribing to it. The subscriber from the controlling Center can also subscribe to additional data such as flight plans and radar tracks that are published by the other Centers. The initial Data Server concept includes sharing of partial-trajectory ETAs, STAs (to outer-arcs and outer-outer arcs), flight plans and tracks between the Centers. The basic concept could be expanded to include site-specific adaptations from neighboring Centers, and control parameters for remote GUI processes.

The design of the DS provides the means for the sectors and ultimately the Centers to unite and form a larger controllable airspace to handle the regional traffic of the northeast. It glues the pieces together forming a regional picture and allows TMCs to better manage traffic.

GUI Router Module

The second new module created for McTMA is the GUI router, whose function is to disseminate traffic and display data from a local site to a remote location.[8] The remote GUI can display timeline data, load graph data, command and control functions from the TGUI, and PGUI track data. Initial functional development focuses on an infrastructure making remote displays possible. Subsequent functionality will allow the remote GUI to display both local and remote data on the same piece of monitor hardware. This is desirable to reduce hardware footprint and clutter in the TMU. When a Center receives more and more adjacent Center data feeds, the effectiveness and efficiency of making cross-reference searches for aircraft across multiple Centers and reference points increases when relevant data are presented on the same piece of hardware.

Working in conjunction with the Data Server, the GUI router makes it possible for the TMCs to visualize the impending traffic and to coordinate with the other Centers to implement the proper traffic management game plan. The GUI router allows the TMCs at different Centers to see the exact traffic picture on each monitor display. The remote GUI process also provides a bridge for the Centers and TRACON to view and share in the inter-facility flow management decision-making process. The remote viewing capability is available to all participating parties.

Operationally, it is the TRACON that imposes the arrival constraints upon the Center, making the participation from the PHL TRACON highly desirable. By tapping into the ZNY McTMA system, the TMC from the PHL TRACON can directly observe and view accurate prediction of traffic as far as the outer boundary of the three adjacent Centers. This powerful visualization capability is not available to the TRACON and Centers today. In addition to the flow visualization aspect, all facilities can scrutinize the flow advisories that McTMA produces based on the flow constraints that all participants have input into the game plan.

EDAR Module

Also new to McTMA is the addition of the ETMS data feed. McTMA integrates the flight plan and aircraft track data it receives from ETMS with the other aircraft in the system generating the demand profile at the airport.[7] As shown in Figure 6, ETMS data is routed to McTMA through the ETMS Data Archive Router software.[3] The EDAR software module was developed for the Traffic Flow Automation System (TFAS) project and is incorporated into the McTMA software to provide the same functionality.[3] A connection with the ETMS national feed at ZNY (primary) and ZDC (backup) will provide flight plan and radar track data for TEC flights into PHL (Figure 5). The TEC flights are not available to the Host because they do not enter the ARTCC airspace. EDAR provides this critical flight data and completes the demand picture at the airport. Initially, the ETMS feed will only be routed to ZNY, which handles TEC flights destined for PHL. Eventually the incorporation of this functionality will provide any McTMA system the ability to access the ETMS data.

The data provided by the WAN allows for the merging of the regional traffic whereas the EDAR process completes the picture inside the TRACON. This EDAR data also contributes to the development of collaboration and trust between the TRACON and Centers. Currently, the TRACON empirically includes the TEC flights into its calculation of the AAR and adds a larger miles-in-trail buffer in its restriction to ZNY. Without McTMA, the TRACON is posting an AAR that gives it some maneuvering space to integrate the TEC flights into the arrival stream but this estimate may be highly inaccurate and inefficient. With McTMA, the scheduler incorporates the TEC flights into the arrival streams and schedules aircraft to all available runway slots, as set by the AAR.

The value of the AAR may change depending on the experience and comfort level of the TMC on duty. McTMA can help normalize the traffic prediction ability of the TMCs although the comfort level will still vary between coordinators. Past experience has shown that after initial use, the value of the AAR will be adjusted to reflect the trust in the system. A similar experience was observed when the TMA system was first introduced to the ZFW and DFW TRACON.[6] While the situation did not involve TEC flights, the TMA cadre team (comprised of ZFW controllers and TMCs from both ZFW and DFW) felt that TMA was capturing the proper level of traffic and workload and as the facility felt more comfortable with the performance of the system, it increased the AAR. Prior to using TMA, the DFW and ZFW facilities used different criteria to define the AAR. When TMA did come online, there was a period of debate about the definition of the AAR. With McTMA, data from ETMS and adjacent Centers will allow all parties to see the larger picture and to start on the same page. A period of clarification about the AAR setting is anticipated.

Modifications to the TMA Core Modules

Changes to all core software modules are required to support the new McTMA features. Both ISM and CM were modified to interface and communicate with the new Data Server module. With the additional EDAR data source, the ISM will have to mosaic more aircraft data and integrate it into the current aircraft database. The CM has the additional task of routing requests and data from the external sources to the GUI router.

RA Modifications

The task of the RA is to generate ETAs for arrival aircraft in single-Center TMA. The RA in McTMA also provides a similar service but it also has new capabilities. RAs running at adjacent Centers will generate ETAs for enroute aircraft. The enroute-ETA calculation is referred to as the partial-trajectory ETA because it represents only one segment (through a particular Center) of the full trajectory for the arrival aircraft. The enroute status is defined relative to the local Center. In the scenario set previously, ZNY is the arriving (and controlling) Center and its RAs produce nominal or arrival ETAs. ZOB and ZBW are adjacent Centers that generate partial-trajectory ETAs and forward the ETA segments to ZNY.

In McTMA, the RA module at the controlling Center has the added task of combining the partial-trajectory ETAs from the adjacent Centers to form an aircraft's ETA profile. This is a critical step in providing an accurate model of the demand picture. In summary, the RA can calculate ETAs for over flights (partial-trajectory ETA), ETAs for arrival aircraft, and has the capability to join the ETA segments to form the ETA profiles.

DP Modifications

The DP module undergoes a similar set of modifications. Like TMA, the DP represents the scheduling module in the McTMA software. In McTMA, DP calculates and provides STAs for aircraft that are owned by an adjacent facility, whether the aircraft are one-tier or even several tiers away. Functional enhancements to the multi-center DP will be completed in two developmental phases. The first phase implements concepts that are considered extensions to TMA but are applicable to the complex environment of the Northeast. This is an interim step. The second phase looks at more advanced concepts and is still under investigation.

In Phase 1, two additional scheduling methods are introduced: multiple outer-arcs and outer-outer arcs. The single-Center DP scheduling algorithms produce three sets of STAs; one at the runway threshold, one at the Center/TRACON boundary or meter fix, and one at the outer arcs.[4] Figure 8 depicts the outer arcs (OA) and outer-outer arcs (OOA) for the arrival streams to the PHL meter fixes.[8] Single-Center DP can generate schedules for flows coming over the PTW, Mazie, Terri and VCN (Arrival Stream 2) meter fixes and their corresponding outer-arcs. The assignments of aircraft to the OOA over the Bunts and VCN (Arrival Stream 1) meter fixes require the development of new scheduling algorithms.

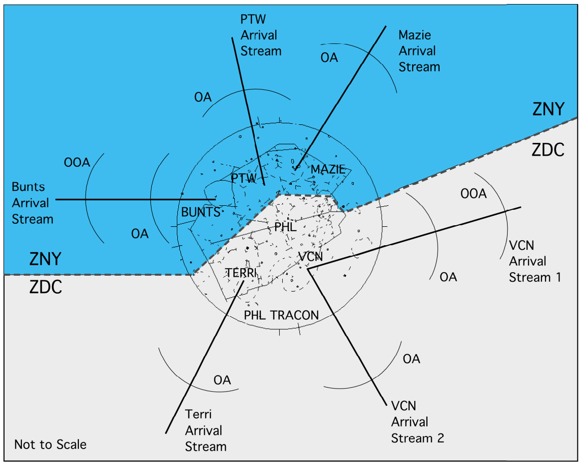

Figure 8: Scheduling Capabilities of McTMA

The OOA concept adds an additional tier of control to the OA notion. The second tier of control offers refinements to the original concept. Controllers working the OOA sectors offer some relief to their counterparts working the OA sector by reducing a portion of the overall delay. This subtlety becomes more apparent in the northeast where controllability within a sector is more restricted. If the Bunts arrivals have to be delayed by six minutes and the OA sector can only absorb two of the six minutes, then it is up to the OOA sector to absorb the other four minutes. In this example, the agreement between the sectors might be such that the OA sector can handle only up to two minutes of delay and the OOA sector will handle as much of the remainder of the delay as it possibly can. If that is not enough, then the OOA sector places additional restrictions on the upstream sector or facility.

While the OOA concept refines the OA concept, the multiple outer-arcs offer additional control at the meter fix. The situation in the northeast requires the flexibility to impose different constraints on aircraft from the same stream class but arriving on different arrival routes. Figure 8 illustrates this condition at the VCN corner post where jets on the Stream 1 (Boston to New York oceanic traffic) route can have different speed or altitude restriction then jets on the Stream 2 (Washington's non-oceanic traffic) route. Eventually, both streams will merge at the VCN meter fix, prior to delivery into the TRACON. The ability to impose multiple constraints on the same stream class (jets to VCN) will aid in this situation.

One limitation of the DP scheduler in TMA is that it can accommodate only one set of freeze horizon setting per stream class per meter fix. The freeze horizon denotes a temporal or spatial location from the meter fix where aircraft sequences and STAs are determined and displayed on the controllers' radarscope. Simulations conducted at NASA Ames showed that for controllability reasons, the freeze horizon had to be set near the outer boundaries of ZOB, ZBW, and ZDC airspace. Unfortunately, as the freeze horizon is set further out, uncertainty in the conformance of aircraft sequence and STA at the meter fix increases.

The Phase 2 development tasks have not been determined yet but the following future concepts are being considered. One concept would be the possibility of using multiple instances of DP within a McTMA system. In effect, each DP works on a subset of airspace thus reducing the freeze horizon, promoting sequence and STA conformance at the metering locations, and providing deconflictions at additional merge points. Another approach would extend the concept even further to include a network of DPs. Both advanced concepts need further investigation. The selection of one of these methods will determine the Phase 2 development. This is a major architecture design departure from the single DP design in the current TMA and McTMA systems.

Adaptation Data Modifications

The adaptation files consisting of system and airspace definitions are modified similarly to what is described for the RA and DP processes. Major changes to adaptation files include defining new metering locations (OA, OOA, multiple meter fix) for the DP, common boundary crossing fixes for the calculation of partial trajectories of enroute aircraft for the RA, routes for the RA to build the partial trajectories, publish and subscribe parameters for the DS, and parameters to display information at the remote displays for the GUI router.

TMA System Compatibility

One objective of the project is to develop a McTMA architecture that is backward compatible with the existing TMA architecture. This allows reuse of most TMA core libraries, such as communication protocols, socket architecture, message types and inter-process messaging. The compatibility issue is addressed every few months when the TMA functionalities are reintegrated into the McTMA baseline. This complex task requires a post-integration functionality verification and validation process. The benefit is that all bug fixes and new enhancements added to TMA then become part of the McTMA system.

When a Center transitions from a TMA system to a McTMA system, the entire core of TMA features will be available plus new McTMA functions. For the most part, the user interface will remain the same, although new user-interaction functionality may be developed to access McTMA features. For sites that already use TMA, this will minimize training time. From the controller's perspective, there will be no noticeable difference within the aircraft meter list displayed on their radar scope.[2]

Inter-Facility Collaboration and Coordination

The McTMA features described in this document complement each other in encouraging the TMU and TMC to actively participate in the planning and execution of the flow management game plan. In summary, McTMA gathers traffic data from adjacent Centers and the TRACON to provide a complete picture of demand, shares the data through a common flow visualization display, and provides advisories (time-based schedules) and possible solutions to the impending traffic demand.

The algorithms being developed for McTMA try to mimic the current operational procedures. The coordination of sector handoffs and the arrangement of in-trail traffic require close interactions between the sectors. The smaller sectors collaborate across boundary lines to solve the bigger traffic control picture. Better coordination between sectors helps set up an arrival flow that is more workable by the receiving sector. The upstream sectors typically have more airspace allowing them to set up a better flow and to absorb a larger percentage of the delays. In essence, the smaller sectors are transforming themselves into a larger airspace to control traffic. The McTMA architecture utilizes this coordination scheme and expands it beyond the sector airspace by including the Centers themselves, via the Data Server, to provide inter-facility collaboration.

One fundamental benefit that McTMA offers, even without the scheduling capability, is the ability to predict the arrival demand on a regional level. Other systems, such as ETMS, provide regional information based on current track data or aircraft situation, but does not provide the prediction capability and accuracy that McTMA offers.

The following topics in this section illustrate other areas where McTMA can provide additional assistance to the TMCs. McTMA can be used to schedule release times for departures from an adjacent airport destined for PHL. Because of its accurate prediction capability, McTMA can eventually remove the disruptive process known as no notice holding, thereby providing a smooth delivery of traffic into the TRACON.

It should be noted that there is an on-going separate study led by Mitre/CAASD that addresses the operational aspect of collaboration and coordination between the Centers and the PHL TRACON. This research will be the basis for future integration and implementation of the McTMA system at other sites. The topics discussed in this section will no doubt be included in the operational concepts document.

Scheduling of Call-For-Release Aircraft

The level of control that McTMA offers will help refine some of the air traffic management methods existing today. Because McTMA can provide accurate STAs, the facilities can collaborate to find the best time to release an aircraft from an airport in a neighboring facility so that it can merge into an open slot in the overhead PHL arrival stream. Possible candidate airports include Pittsburgh, Cincinnati, and Boston Logan.

The current call-for-release method begins when the tower TMC initiates a phone call to the TMC at the Center. The tower indicates that it would like to release a PHL bound aircraft, say USA1217, at a specific time. The Center TMC draws on past experiences to determine if the Center has a slot to accommodate USA1217 in the PHL arrival stream. The Center TMC estimates the climb-out time for the aircraft to join the overhead stream and selects a slot. The TMC has the flexibility to advance or delay the departure time and relays that time to the tower TMC. This is a tedious process that may or may not work well, and requires some knowledgeable guesswork that varies with each coordinator's skill.

The process also has a significant shortcoming because it involves making the judgment based on a single Center's limited view of the traffic. A call-for-release made to benefit one Center now may cause a cascade of problems downstream. This in turn may cause more problems upstream when the hand-offs to the downstream facility are rejected due to overcapacity.

One McTMA operational concept dealing with call-for-release aircraft has the Center TMC selecting the slot that the aircraft is going to occupy in the arrival stream. Using the TGUI interface, the TMC drags-and-drops the aircraft call sign into the slot and a release strip is automatically printed out at the tower. The scheduler determines a departure time that is conflict-free at the arrival runway, reserves a slot for the call-for-release aircraft in the arrival stream and a corresponding slot at the runway. If necessary, appropriate delays will be applied to satisfy the AAR. Ideally, the decision to make the assignment of the call-for-release aircraft should come from the Center that owns the departure airport. This keeps the authoritative structure in line with the current operational procedures.

No-Notice Holding

The no-notice holding situation occurs when a downstream facility is at or over capacity and refuses to accept any more hand-offs from the upstream or feeding facility. This occurs with some frequency and without notice between the northeast Centers. It is very disruptive to the facilities and creates a very tense and antagonistic working environment. When the downstream facility "shuts its gate", the upstream facility must do whatever it can to control the aircraft it currently owns. This typically means giving the order to fly the holding pattern. The sector takes further protective action by passing upstream more restrictive constraints (i.e. larger in-trail separation).

Getting mired in a no-notice situation is undesirable and unpleasant. This circumstance also hampers the controller's ability to strategize a plan that provides a smooth and steady flow of traffic after the expiration of the no-notice period. When the receiving facility is again able to accept handoffs, the resumption of the traffic flow is often very inefficient. Aircraft from the upstream sector may not be at the best speeds, headings, or altitudes to immediately resume their flight path over the metering point or arrival gate. During the recovery period, the upstream sectors may not have enough aircraft in the queue to deliver a nominal load thereby forfeiting landing slots. This creates inefficiencies at both the sector and the airport because of under-utilization.

Through the TGUI or PGUI displays (via the GUI router), the regional demand and delay profiles are made available to all facilities. Each Center can detect the impending demand problem in advance and devise plans to correct the problem, thus avoiding the disruptive domino effect when a gate is suddenly closed.

If holding is still required, however, regional demand and delay profiles on the TGUI and PGUI provide information to execute a systematic recovery. The upstream facility will be able to more efficiently queue up and resume delivery of traffic to the downstream facility. This reduces the inefficiencies that occur when resuming from a holding situation. The queue is always being updated in McTMA because aircraft states and demand predictions are constantly being updated.

Other Applications

Rerouting of aircraft from one gate to another gate is an optional procedure that is available to each Center. However, it is very labor-intensive and seldom exercised. With McTMA, this method of traffic management can be exercised more often as a way of coping with moving weather fronts, for example. Gate reroutes can be put into effective use when a weather cell forces the closure of one or more gates. Rerouting can be a preferred option compared to extended holding or diversion to nearby airports. The reroute can be done while the aircraft are still in an upstream Center.

The traffic management supervisors and sector managers can also use the traffic prediction capability to determine staffing levels at each air traffic control unit. The appropriate staffing level can be determined for sectors that will be impacted and during which shift that congestion occurs.

Concluding Remarks

The use of McTMA will open up and foster a new level of collaboration and coordination between the facilities. In effect, McTMA unites the individual Centers to create a super Center. The ability to "join" the airspace is not limited to the northeast Centers. It is available to any Centers that choose to unite and form the McTMA network. Figure 9 illustrates the imaginary united super-Center of the Northeast that will collaborate to control PHL arrivals. The super-Center controllable airspace is larger than the overlaying Fort Worth Center airspace.

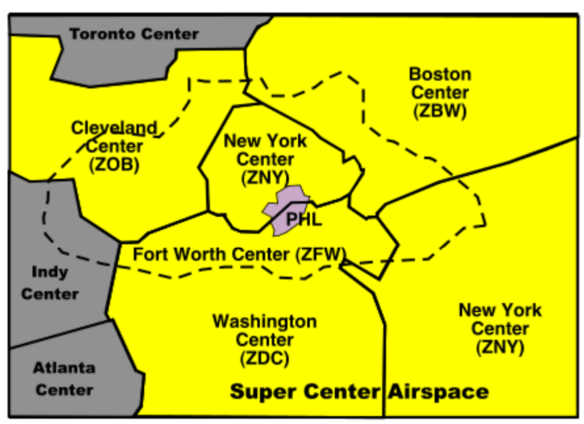

Figure 9: Effective "Super-Center" Airspace

The opportunity now exists to allow control of PHL arrivals at control points that are well beyond the border of the TRACON airspace. The combined airspace will allow the facilities to develop and exercise new traffic management techniques that were not available before.

The prototype McTMA system in the northeast has all Centers collaborating to provide data for only PHL arrivals. Ultimately, all Centers would have a complete McTMA system, and each Center could provide arrival data for all congested airports in the northeast. In addition to PHL, other candidate airports with similar needs for a multi-Center management of its arrivals are La Guardia, Ronald Reagan National, Washington Dulles, Boston Logan, and JFK.

One day, even Indianapolis and Atlanta Center may choose to participate. A Center does not have to have major congested airports within its boundaries to take advantage of the features that McTMA offers. The Centers can use the call-for-release feature to inject aircraft into the smooth flowing enroute stream.

The prototype McTMA systems will be installed in the four Centers and the PHL TRACON at the end of summer 2002. The systems will run in development rooms shadowing the operational traffic. This period will be used to train the cadre on the features of McTMA and to devise an initial game plan. The partial-trajectory ETA algorithm will be scrutinized for accuracy as well as the joining of ETAs across Centers. The following summer brings in the new scheduling algorithms, which will undergo exhaustive testing. Lastly, the transfer of technology and prototype system to the FAA will occur near the end of 2004.

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